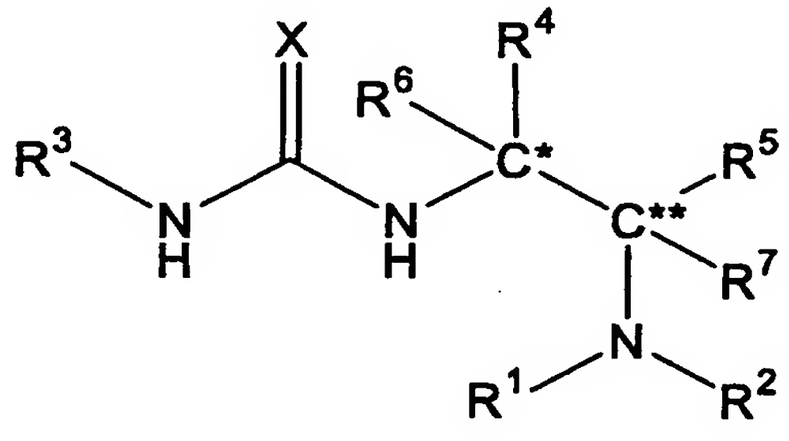
Claims

1. A compound represented by the formula (I):



(I)

wherein

X is an oxygen atom or a sulfur atom;

C^* and C^{**} are each independently an asymmetric carbon;

R^1 and R^2 are

the same or different and each is a lower alkyl group optionally having substituent(s), an aralkyl group optionally having substituent(s) or an aryl group optionally having substituent(s), or R^1 and R^2 optionally form, together with the nitrogen atom they are bonded to, an aliphatic heterocycle optionally having substituent(s) (the aliphatic heterocycle is optionally condensed with an aromatic hydrocarbon);

R^3 is

a lower alkyl group optionally having substituent(s), an aralkyl group optionally having substituent(s), an aryl group optionally having substituent(s) or a heteroaryl group optionally having substituent(s);

R^4 and R^5 are

the same or different and each is a lower alkyl group optionally having substituent(s), an aralkyl group optionally having substituent(s) or an aryl group optionally having substituent(s), or R^4 and R^5 optionally form, together with the asymmetric carbons they are respectively bonded to, a homocyclic ring optionally having substituent(s) or a heterocycle optionally having substituent(s); and

R^6 and R^7 are

the same or different and each is a hydrogen atom or a lower alkyl group optionally having substituent(s),

or a salt thereof.

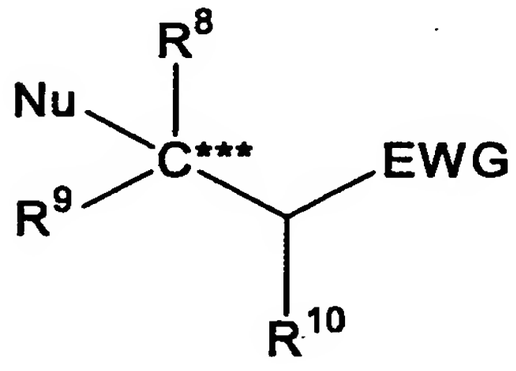
2. The compound of claim 1, wherein X is a sulfur atom, or a salt thereof.

3. The compound of claim 1 or 2, wherein R^4 and R^5 form, together with the asymmetric carbons they are respectively bonded to, cyclopropane, cyclobutane, cyclopentane or cyclohexane, or a salt thereof.

4. The compound of claim 3, wherein R^4 and R^5 form cyclohexane together with the asymmetric carbons they are respectively bonded to, and R^6 and R^7 are each a hydrogen atom, or a salt thereof.

5. The compound of claim 4, wherein the absolute configurations of C* and C** are both S-configurations or both R-configurations, or a salt thereof.

6. A method of producing a compound represented by the formula (IV):



(IV)

wherein

C^{***} is an asymmetric carbon;

R^8, R^9 and R^{10} are

the same or different and each is a hydrogen atom, a lower alkyl group optionally having substituent(s), an aralkyl

group optionally having substituent(s), an aryl group optionally having substituent(s), a heteroaryl group optionally having substituent(s), a hetero atom optionally having substituent(s) or an electron withdrawing group, or R^9 and R^{10} optionally form, together with the carbon atoms they are respectively bonded to, a homocyclic ring optionally having substituent(s) or a heterocycle optionally having substituent(s), provided that R^8 and R^9 are not the same groups;

EWG is

an electron withdrawing group selected from a nitro group, a cyano group, $-COR^{11}$, $-SO_2R^{12}$, $-COOR^{13}$ and $-PO(OR^{14})(OR^{15})$

wherein

R^{11}, R^{12}, R^{13}, R^{14} and R^{15} are the same or different and each is a hydrogen atom, a lower alkyl group optionally having substituent(s), an aralkyl group optionally having substituent(s), an aryl group optionally having substituent(s) or a heteroaryl group optionally having substituent(s), or R^{11} and R^8, or R^{11} and R^{10}, optionally form, together with the carbon atom(s) they are respectively bonded to, a homocyclic ring having an electron withdrawing group and optionally having substituent(s); and

Nu is

$-CR^{16}(COR^{17})(COR^{18})$, $-OR^{19}$, $-SR^{20}$, $-NR^{21}R^{22}$, $-C(NO_2)R^{23}R^{24}$

wherein

R^{16} is a hydrogen atom, a halogen atom, a hetero atom having substituent(s), a lower alkyl group optionally having substituent(s) or an aryl group optionally having substituent(s);

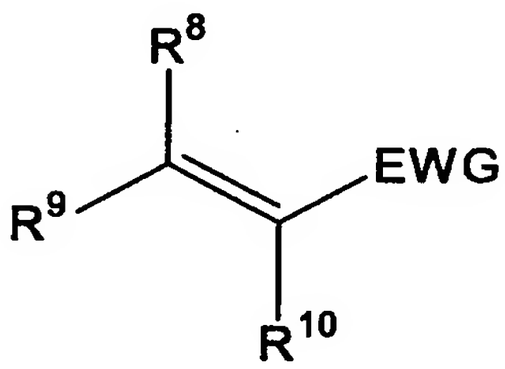
R^{17} and R^{18} are the same or different and each is a hydrogen atom, a lower alkyl group, a lower alkoxy group, a mono-lower alkylamino group or a di-lower alkylamino group;

R^{16} and R^{17} optionally form, together with the carbon atoms they are respectively bonded to, a homocyclic ring optionally having substituent(s) or a heterocycle optionally having substituent(s) (the homocyclic ring and heterocycle are optionally condensed with an aromatic hydrocarbon); and

R^{19}, R^{20}, R^{21}, R^{22}, R^{23} and R^{24} are the same or different and each is a hydrogen atom, a lower alkyl group optionally having substituent(s), an aralkyl group optionally having substituent(s), an aryl group optionally having substituent(s) or a heteroaryl group optionally having substituent(s), or R^{21} and R^{22} optionally form, together with the nitrogen atom they are bonded to, an aliphatic heterocycle optionally having substituent(s), or

an azido group,

or a salt thereof, which comprises conjugately adding a nucleophilic reagent represented by the formula (III): H-Nu (III) wherein Nu is as defined above, to a compound represented by the formula (II):



(II)

wherein each symbol is as defined above, or a salt thereof, in the presence of a compound or a salt thereof of any of claims 1 to 5.

7. The method of claim 6, wherein Nu is $-CR^{16}(COR^{17})(COR^{18})$, $-OR^{19}$, $-SR^{20}$, $-NR^{21}R^{22}$, $-C(NO_2)R^{23}R^{24}$

wherein

R^{16} is a hydrogen atom, a halogen atom, a lower alkyl group optionally having substituent(s) or an aryl group

optionally having substituent(s);
R^{17} and R^{18} are the same or different and each is a hydrogen atom, a lower alkyl group, a lower alkoxy group, a mono-lower alkylamino group or a di-lower alkylamino group;
R^{19}, R^{20}, R^{21}, R^{22}, R^{23} and R^{24} are the same or different and each is a hydrogen atom, a lower alkyl group optionally having substituent(s), an aralkyl group optionally having substituent(s), an aryl group optionally having substituent(s) or a heteroaryl group optionally having substituent(s), or R^{21} and R^{22} optionally form, together with the nitrogen atom they are bonded to, an aliphatic heterocycle optionally having substituent(s), or an azido group.

8. The method of claim 6 or 7, wherein the electron withdrawing group for EWG is a nitro group.

9. The method of any of claims 6 to 8, wherein R^8 and R^{10} are each a hydrogen atom, and R^9 is a lower alkyl group optionally having substituent(s), an aryl group optionally having substituent(s) or a heteroaryl group optionally having substituent(s).

10. The method of any of claims 6 to 9, wherein the nucleophilic reagent (III) is represented by $HCR^{16}(COR^{17})(COR^{18})$ wherein each symbol is as defined above.

11. The method of claim 10, wherein R^{16} is a hydrogen atom, a lower alkyl group optionally having substituent(s), a halogen atom or a hetero atom having substituent(s), and R^{17} and R^{18} are the same or different and each is a lower alkoxy group.

12. The method of claim 11, wherein R^{16} is a hydrogen atom, methyl, a chlorine atom, methoxy or tert-butoxycarbonylamino,

and R^{17} and R^{18} are each methoxy or ethoxy.

13. The method of claim 10, wherein R^{16} and R^{17} optionally form, together with the carbon atoms they are respectively bonded to, a homocyclic ring optionally having substituent(s) (the homocyclic ring is optionally condensed with an aromatic hydrocarbon).

14. The method of claim 13, wherein the homocyclic ring is 1,2,3,4-tetrahydronaphthalen-1-one.

15. The method of any of claims 6 to 14, which is performed in at least one solvent selected from toluene and methylene chloride.

16. The method of any of claims 6 to 14, which is performed without a solvent.